Minamikatamura (leg. T. TUYAMA, Aug. 9. 1932); Prov. *Nagato*: Nakaono in oppido Misumi-mura (leg. D. NIKAI, no. 2829, Aug. 11. 1920); Prov. *Suwô*: Simadi in oppido Simadi-mura (leg. D. NIKAI, no. 2961, Sept. 16. 1920); Prov. *Awa (Sikoku)*: in oppido Kamomyô-mura (leg. D. NIKAI, no. 2372, Sept. 16. 1920); Prov. *Tosa*: in oppido Kamo-mura (leg. T. MAKINO), in oppido Ogawa-mura (leg. T. TUYAMA, Jul. 31. 1934); Prov. *Tikuzen*: in oppido Madamura (leg. Y. NABESIMA, no. 9, Sept. 10. 1928); Prov. *Hyûga*: in monte Hyûganisitake (leg.? no. 7, Aug. 5. 1882).

Distr. Japonia.

牧野根本兩氏共著日本植物總覽ニ和文記載ヲツケテ **Fimbristylis diphylloides** MAKINO トシテ發表サレタノミナノデ玆ニ羅丁文記載ヲ附スル。莖ハ5稜形デ葉ト別ニ生ジ約30 cm. ニ達シ細ク直立スル。灰黑色ノ小穗ヲ5–15個粗ニ生ズル。雄蘆1及自2個、柱頭ハ2岐稀ニ3岐スル。果實ハ扁壓サレタル倒卵形體デ表面ニ網狀ノ紋ガアル。

Studies on "Tengu-no-mugimeshi",(1)

a mass vegetation of micro-organisms indigenous to some volcanic regions in the middle part of Japan proper

by

MOTOO TAKAHASHI

高橋基生：「天狗ノ麥飯」ノ研究（其一）

I. Occurrence and appellation of the vegetation

"Tengu-no-mugimeshi" which is called also "Iizuna" (飯砂-eatable sand), "Iitsubu" (飯粒-eatable grains) or "Miso-tsuchi" (味噌土),(2) is known from old times as a wonderful mass vegetation of micro-organisms growing in some volcanic mountains in the province of Shinano (信濃). The names of some

(1) "Tengu-no-mugimeshi" means the barley-bread of a demon.

(2) "Miso-tsuchi" means the soil like "Miso," which is a sort of bean paste needed for Japanese soup consomme.

places, for instance, Mt. Iizuna (飯綱山), Mt. Misozuka (味噌塚山) and Mt. Wari (割山)[1] have been derived from the appearance of the vegetation. But the exact date of its discovery is uncertain. As the oldest literature in which this curious vegetation is described, we can mention the following two books:—"Zenkojido-meisho-zukai" (善光寺道名所圖會) and "Shinsho-kisho-roku" (信勝奇勝錄), both published in the age of Tempo (天保) (1830–1843).

As the localities producing this vegetation, we can give at present twenty spots or so distributed in ten districts:—Mt. Kurohime (黑姬山), Mt. Togakushi (戸隱山), Mt. Motodori (髻山), Mt. Madarao (斑尾山), Mt. Misozuka, the village of Shinanojiri (信濃尻村) and its neighbourhood, several places in Mt. Myoko (妙高山), three places in the vicinity of Mt. Gippa (牙山) and eight places near and around of Kazawa hot spring (鹿澤溫泉) which the author visited recently. Curious to say, the occurrence of this vegetation is limited to some volcanic mountains more than one thousand meters high, and these volcanoes belong without exception to the Fuji volcanic zone (富士火山脈), lying in the Shinano province or its neighbourhood. But it might be rush to conclude from this fact that the vegetation does not grow elsewhere. It is rather curious that a similar observation has hitherto been recorded from no other parts of the world.

II. History of the studies hitherto

Bacteria-mass theory—"Tengu-no-mugimeshi" came into question in the scientific world in 1880 or so, namely about half a century ago for the first time. The late Dr. Naoe OONO,[2] then a student of the Imperial University of Tokyo, is the first who studied this queer mass vegetation. He sketched this mass under the microscope (cf. Fig. 1) and observed the colouring reactions by various reagents:—fuchsin, methylblue, congo-red, jode, Millon's reagent, sulphuric acid, hydrochloric acid, acetic acid, nitric acid, potash, ammonium oxalate or hydrochloric acid, and potassium ferro-cyanide. Further, he observed the changing state putting this mass into the boiling water. Besides, he tried to cultivate this vegetation on the gelatin-plate containing pep-

(1) "Wari"="Hiki-wari-meshi" which means also the barley-bread.

(2) N. OONO: Untersuchung über "Tengu-no-mugimeshi", gefunden auf dem Berge Kurohime-yama. The Botanical Magazine. Vol. XXX, (1916) March. (Japanese).

tone and beef-extract. On the ground of this experiment, he reported that he had succeeded in the pure-culture of the following bacteria and algæ separated from the mass.

1. *Bacillus sp.* No. 1
2. *Bacillus sp.* No. 2
3. *Phycomycetes sp.*
4. *Kapselbacteria sp.*
5. *Leucocystis sp.*

As to the physiological actions of "Tengu-no-mugimeshi" he referred only supplementally. And regretably, he suspended this study after a few years.

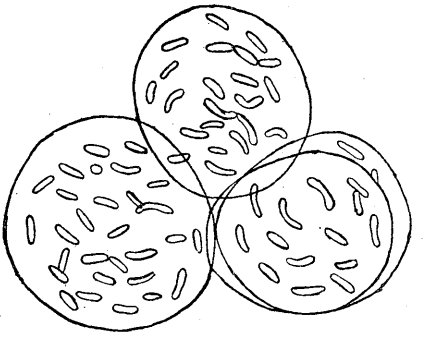

Fig. 1. The micro-organism sketched by late Dr. Oono. (×1000)

Independent of this Oono's research, Dr. Tamiji Kawamura[1] began to study this vegetation in 1910 or so. According to the observation under the microscope, "Tengu-no-mugimeshi" is a mass of gelatinous and transparent grains having the shape of sphere or ellipsoid, which are 5–30 μ in diameter ; and in the central part of each grain, corpuscles of various shapes like bacteria are visible. On the basis of the concentric circles which developed when this grain was delt with a dilute acid solution, he ascertained the concentric constructions of this gelationous grain. And he tested colouring reactions by various reagents. Besides. he cultivated this grain in various ways[2] with a mere result that he succeeded only in separating various kinds of bacteria mixed among grains. Thus he seems to have failed in the cultivation of the substancial micro-organisms.

He touched on the position of the micro-organisms composing "Ten-u-no-mugimeshi" from the taxonomical point of view. Comparing these micro-organisms with thread-shaped bacteria, he allowed some resemblances to these four species in the following, upon these points—shape like thread, covered

(1) T. Kawamura, Studies on "Tengu-no-mugimeshi," a mass bacterial vegetation I. The Botanical Magazine. Vol. XXX. (1916) No. 353. (Japanese).

(2) T. Kawamura, Studies on "Tengu-no-mugimeshi," a mass bacterial vegetation II. The Bo anical Magazine. Vol. XXX. (1916) No. 354. (Japanese).

with a sheath and propagation by Gonidia.

1. *Crenothrix polyspora* COHN. (=*Crenothrix Kühniana* ZOPF.)
2. *Cladothrix dichotoma* COHN. (=*Sphærotilus dichotoma* COHN)
3. *Chlamydothrix ochracea* (KÜTZING). (=*Leptothrix ochracea* KÜTZING)
4. *Spirophyllum ferrugineum*(EHRBG). (=*Gallionella ferrugineum* EHRBG)

But, he concluded on decisive grounds tnat these micro-organisms could not be identified mith any of them. Therefore, he set up a new genus and species as follows :—*Vulcanothrix silicophila* n. g., n. sp..

He added further that in the mass of "Tengu-no-mugimeshi" he found species of *Oomycetes* and of *Micrococcus*, *Bacillus fluorescens* and *Bacillus mycoides*.

In short, according to Dr. KAWAMURA'S opinion, the fundamental body of the mass is composed of thread-shaped bacteria.

In 1920, Dr. MIYOSHI,[1] a member of the Committee of the Preservation of Natural monuments and Historical remains, recommended the growing place of "Tengu-no-mugimeshi" in Mt. Misozuka as a natural monument; and in the next May, this selection officially announced. In the explanation about the place, he said that they were cultivating *Soya* and other crops on the growing place of the micro-organisms since the last year, but their growth was bad, promising poor yield. This is an innegligible fact for the physiological and ecological study on "Tengu-no-mugimeshi."

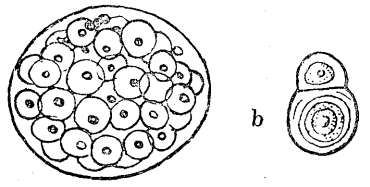

Fig. 2. a—A kind of micro-organism sketched by Dr. KAWAMURA.
b—The developed concentric circle of a grain in a dilute acid (×1000) (KAWAMURA)

Lower alga theory—Dr. Y. ENDOO referred to "Tengu-no-mugimeshi" in his work, "Marine Plants"[2] and said that this organism belonged to Nostocaceæ. But he stated nothing of its reason.

Next, we must introduce the opinion of Dr. HANS MOLISCH and Dr.S. STOCK-

(1) M. MIYOSHI, Report of the Committee of the Preservation of Natural monuments and Historical remains. (1921.) No. 13. (Japanese)
(2) Y. ENDOO, Marine Plants. (1911.) p. 196. (Japanese)

MAYER. The former, who visited Japan in 1922, expressed his opinion about this micro-organism in his work "Pflanzenbiologie in Japan."[1] He was given some sample produced in Mt. Kurohime by Dr. KAWAMURA and observed it under the microscope. He became doubtful of the OONO'S and KAWAMURA'S bacteria theory, and thought that this strange mass of micro-organism mainly composed of some genera of Chroococcaceæ.

He thought that these genera should belong to *Gloeocapsa* and *Gloeothece*; but for the purpose to make sure of this classification, he sent some sample to Dr. S. STOCKMAYER, an authority on the Taxonomy of algæ. Dr. STOCKMAYER not only recognized the genera as above mentioned, but also fixed the species of the micro-organisms which are forming a queer mass vegetation indigenous to some volcanic regions in the middle Japan, by the only observation under the microscope as follows :—

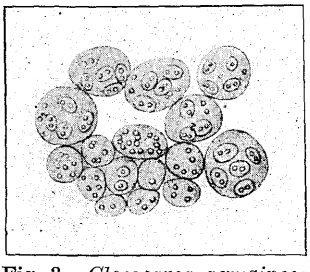

Fig. 3. *Gloeocapsa aeruginosa* KÜTZ. and *Gl. punctata* NAEG. (× 500) (Molisch)

1. *Gloeocapsa punctata* NAEG.
2. *Gloeocapsa æruginosa* (CARM) KÜTZ. and *Gl. conglomerata* KÜTZ.
3. *Gloeothece lineais* NAEG.
4. *Microcystis incerta* LEM.
5. *Gloeothece palea* (KÜTZ.) ROBH.
6. *Lyngbya sp.*
7. Some thread-shaped bacteria

At any rate, we must be grateful to their works, for it might be thought that these works offered a new guidance in the study on "Tengu-no-mugimeshi." But we cannot be satisfied with their works only; and we must admit more possibilities for new facts and new theories about this micro-organism.

In 1934, Mr. M. KATOO and his three cooperators gave the results of their research in the Report of the Imperial Government Institute for Nutrition.[2] According to their report, a typical grain of the mass of "Tengu-no-mugimeshi" is 1—10 mm in diameter, and has an appearance and touch of a boiled

(1) Hans MOLISCH, Pflanzenbiologei in Japan. (1924.) p. 104-109.

(2) Report ef the Imperial Government Institute for Nutrition. Vol. VIII. (1934.) No. 1 (Japanese)

rice grain, when seen with the naked eye. The grain of the mass which sticks to a rock surface, has an irregular plate-like shape, while the mass which is called "Miso" or "Yakesobu" has somewhat granular or clay-like appearance. The colour of the mass is brownish or grayish in various depth. Though it sometimes hardly smells, it has essentially no smell, being somewhat transparent, of no colour and of no taste. The extract of the mass in water has generally the pH of 4.4—5.9. Stored long, it always increases the depth of its colour, but it does not show the tendency of putrefaction. When dried, the grain changes into a dark sand-like one ; when dipped in water, it restores its former appearance again, though it becomes darker ; that is, it has so-called reversible gelationous nature. The substantial micro-organism of "Tengu-no-mugimeshi" under the microscope is sphere-like, transparent and gelatinous fundamental body which is 50–20 μ in diameter and contains rather deflactive and bacteria-like substances. As for the shape, this micro-organism resembles most to *Gloeocapsa*. The reason why "Tengu-no-mugimeshi" is coloured in the ordinary case, seems to be attributed to some adsorpted materials from the rock and soil. And indeed, the testing reactions of Phycocyan and Carotin are negative. Besides, it never propagates in any kind of culture solution as well as on a plate of agar. Even in the case of separating tests on the various solid culture ground, the colonies which grow up, are rather few as compared with the number of the planted grains of "Tengu-no-mugimeshi." The purer the sample is, the more marked is this tendency. So, the separated bacteria must be considered as mere impurities, having no essential relationships with the cause of the growth of "Tengu-no-mugimeshi." When organic or inorganic nurture is rich, the propagation of various bacteria is remarkable, while the grains of "Tengu-no-mugimeshi" are apt to diminish. Considering these facts, the substantial micro-organism in "Tengu-no-mugimeshi" of the sample brought by them to their laboratory is thought to be dead already; or at least a certain unknown condition is needful for its propagation.

In short, the subject does not seem to be settled before the artificial propagatioh should succeed.

Beside these reports, the author has heard of the studies on this micro-orga-

nism by Dr. K. KOMINAMI, Dr. Y. OKADA, Mr. E. FUKUSHIMA and the Institute of Physical and Chemical Research, but their reports are not published yet. So the author should refrain from touching on their works for the sake to avoid misreport. Prof. Dr. H. NAKANO to whom the author is greatly obliged, also has studied this peculiar micro-organism.

III. Studies by author

1. Ecological study

During ten days in the mid-autumn, 1934, the author explored new eight

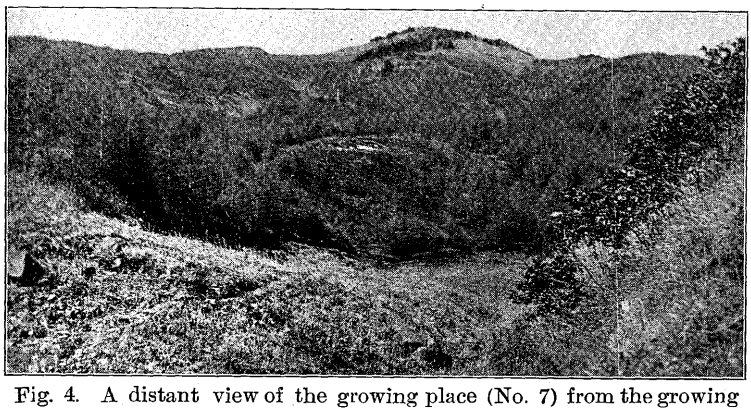

Fig. 4. A distant view of the growing place (No. 7) from the growing place (No. 8) in Mt. Wari.

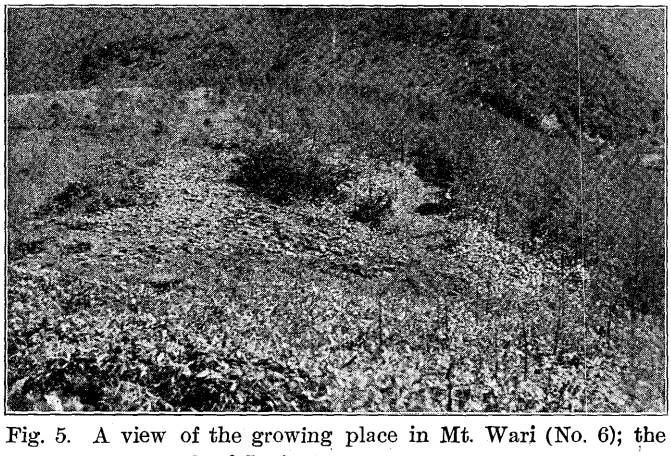

Fig. 5. A view of the growing place in Mt. Wari (No. 6); the poor growth of Larix trees.

growing places of "Tengu-no-mugimeshi" near and around the Kazawa hot spring which situated ten kirometers north-westward from the famous volcano Mt. Asama. For convenience' sake, the author will compare the conditions of these growing places with each other in the following table.

Place name	Height and position	Area and depth	Environment and growing state
Wakuma-zawa (No. 1)	1530 m, south side of a dale	30 squaremeters, 0.2 m–1 m under-ground	covered with herbs, but exposed spotedly
Torazu-sawa (No. 2)	1500 m, west side of a dale	10 squaremeters, surface–0.8 m under-ground	exposed, bordered with herbs
Iwo-zawa (No. 3)	1450 m, half-way up, east side	very small area, earth surface	mixed with the soil, covered thinly with herbs
Iwo-zawa (No. 4)	1450 m, half-way up, south side	very small area, earth surface	in cracks of a rock or among stones
Mt. Takamine (No. 5)	1890 m, half-way up, north side	200 squaremeters, surface–2m underground	exposed or covered with pieces of rock
Mt. Wari (No. 6)	1740 m, half-way up, south-east side	15 squaremeters, surface–1.5 m under-ground	half exposed, half covered with herbs
Mt. Wari (No. 7)	1700 m, half-way up, south-east side	7 squaremeters, 0.15–0.68 m underground	half exposed, half covered with herbs
Mt. Wari (No. 8)	1630 m, at the foot, south-east side	probably very large area (particularly unknown)	far underground, mixed among decomposed rocks

According to this table "Tengu-no-mugimeshi" is found half-way up or at the foot of a mountain or in a dale, of the place of 1450–1890 m in height. As the table shows, the growing places differ in area. Regarding the growing state, some growing places are exposed, others are covered with herbs or pieces of rock. Sometimes we find the grains of "Tengu-no-mugimeshi" cling compactly to the roots of herbs. Considering this fact, it might be supposed that there is a close relationship between "Tengu-no-mugimeshi" and the roots of herbs. But in such a damp and shaded soil as the lower part of the

growing place of Wakuma-zawa (No. 1), or in the dale of Torazu-sawa(No. 2), the grains are entirely exposed like sands on the sea-side. So, being covered with herbs seems to be a mere convenient condition for avoiding the direct sunlight or for keeping dampness. At present I should like to refrain from giving the positive conclusion.

Next, the author will explain the relationships between "Tengu-no-mugi-meshi" and other plants in the plant sociological point of view in the following table.

covering-degree	Wakuma-zawa (No. 1)	Toorazu-sawa (No. 2)	Mt. Takamine (No. 3)	Mt. Wari (No. 6 and No. 7)
5 (50–100%)	no coresponding species	*Arundinaria glabra*	*Arundinaria glabra*	*Arundinaria glabra*
4 (25–50%)	*Arundinaria glabra* *Arundinella hirta* *Scirpus fuirenoides* *Miscanthus Matsumurae*	*Carex oxyandra*	*Carex oxyandra*	*Arundinella hirta* *Scirpus fuirenoides*
3 (12.5–25%)	*Carex oxyandra* *Osmunda cinnamomea* *Metanarthecium luteo-viride* *Aletris foliata*	no corresponding species	*Metanarthecium luteo-viride* *Patrinia gibbiferum* *Vaccinium Vitis-Idaea* *Schizocodon soldanelloides* *Gaultheria Miqueliana*	*Miscanthus Matsumurae* *Carex oxyandra* *Larix Kaempferi* *Rubus microphyllus*
1 (less than 6.25 %)	*Osmunda japonica* *Gentiana Makinoi* *Schizocodom soldanebloides* *Dryopteris nipponica* *Rhododendron japonicum* *Vaccinium Vitis-Idaea* *Sphagnum sp.* *Cladonia sp.* *Lycopodium obscurum*	no corresponding species	*Aletris foliata* *Parnassia palustris* *Solidago japonica* *Pulsatilla cernua* *Vaccinium viginosum* *Larix Kaempferi* *Sorbus commixta* *Tripetaleia bracteata* *Cnidium ajanense* *Lycopodium obscurum*	*Schizocodon soldanelloides* *Scabiosa japonica* *Solidago japonica* *Pteridium aquilinum* *Gentiana Makinoi* *Vaccinium viginosum* *Erigeron annuus* *Eupatorium hakonense* *Malus Sieboldii* *Hydrangea paniculata* *Betula Tauschii*

As this table shows, *Arundinaria glabra* NAKAI is the most dominant spe-

cies, and *Carex oxyandra* KUDO, *Arundinella hirta* KOIDZ. var. *ciliata* KOIDZ. and *Scirpus fuirenoides* MAXIM. are next to it. These plants are growing in the soil which remains thinly over the layer of "Tengu-no-mugimeshi"; sometimes their root-systems spread themselves far into the layer. But they do not seem to have been influenced by the injurious actions which are caused directly or indirectly by "Tengu-no-mugimeshi." On the contrary, as to the growth of *Larix Kaempferi* SARG. there exists a remarkable difference between that in the growing place of "Tengu-no-mugimeshi" and that in its neighbouring soil. In Mt. Wari, all *Larix* trees which were planted in 1918, are only half a meter high (cf. Fig. 6); and they are merely as thick as a thumb; and moreover among them considerable numbers of dead trees are mixed in the growing place of "Tengu-no-mugimeshi". While in the neighbouring soil the same trees are two and a half meters high and 0.1—0.12 m in diameter. Judging from the growth of the latter *Larix*, the soil itself can not be considered worse than in the ordinary case. So the poor growth of *Larix* in the growing place of "Tengu-no-mugimeshi" must be attributed to "Tengu-no-mugimeshi" itself. As the author supposes, this injury primarily comes from the starvation of nutrition, which is the necessary result of the fact that the roots of *Larix* are set free from the soil by the growth of "Tengu-no-mugimeshi"; and secondarily, from a considerable acidity of the growing place (pH 5.4—5.3); and thirdly, from the suffocation of roots, in consequence of the roots being kept from oxygen by the generation of methane gas in the growing place, and by the too much water, contained in the mass of "Tengu-no-mugimeshi." Those injurious actions should occur

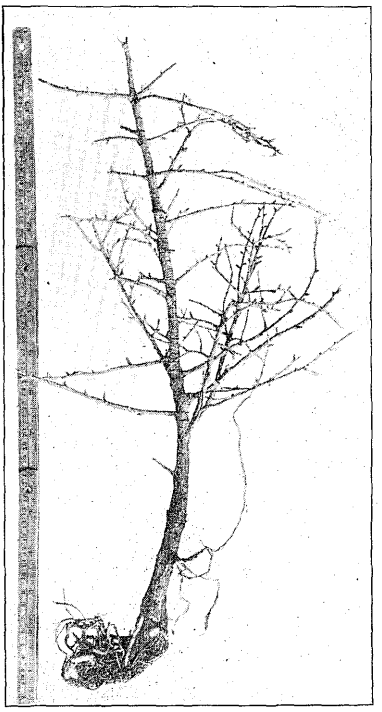

Fig. 6. A dwarf *Larix* tree in the growing place of Mt. Wari (No.6)

not ouly in the case of *Larix*, but also in that of other plants—*Arundinaria glabra*, *Carex oxyandra*, *Arundinella hirta* and *Scirpus fuirenoides*. While in reality, these plants are not affected so much by the above injurious actions, so we cannot think but that these plants have a strong resisting function against those actions.

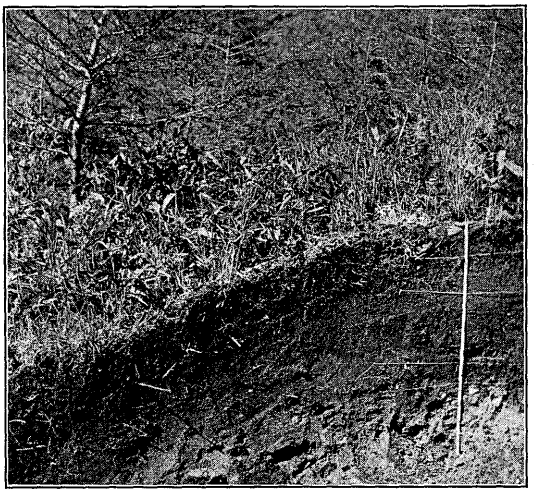

Fig. 7. A sectional view of the growing place in Mt. Wari (No. 7)

For the purpose to investigate the vertical distribution of "Tengu-no-mugimeshi," the author cut down a part of the growing place in Mt. Wari (No. 7) as Fig. 7 shows, and got the following table based on the observation.

	thickness of layer	Sate of layer	pH
1st layer	surface—15 m underground	black humus, living roots of *Arundinaria* and *Carex* mixed	5.3
2nd layer	15—28 cm underground	young and fresh grains of "Tengu-no-mugimeshi" grow, showing blackish brown	5.5
3rd layer	28—55 cm underground	black and clay-like "Tengu-no-mugimeshi," having a smell, decomposition recognized	5.4
4th layer	55—68 cm underground	brown soil, decayed roots of *Arundinaria* mixed	5.4
5th layer	lower than 68 cm underground	brownish gray clay	5.4

If we trace horizontally—in the photo. (Fig. 7) leftwards—along the 4th layer which contains decayed roots *Arundinaria*, the 2nd and the 3rd layers

become thiner and thiner ; and at last, they vanish between the 1st and the 4th layers ; that is, the 1st comes in contact with the 4th. Judging from this observation, it seems to be the case that the orignal growing place of *Arundinaria* was thrown up as "Tengu-no-mugi-meshi" propagated horizontally. Supposing from the condition of decayed roots contained in the 4th layer, ten years or so might have lapsed before the layer of "Tengu-no-mugimeshi" became to the present thickness. It is true that the rapidity of the propagation of "Tengu-no-mugi-meshi" is different with its growing place, but it is sure that it does not propagate so rapidly.

Fig. 8. A view of the growing place in Toorazu-sawa (No. 2), where "Tengu-no-mugi-meshi" is exposed.

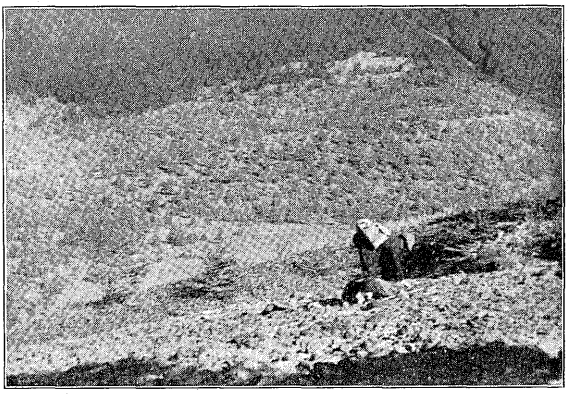

Fig. 9. A view of the growing place in Mt. Takamine (No. 5) covered with pieces of rock.

The author determined the pH of soils as many as possible by the colouring method, beside the soil of Mt. Wari (No. 7) as shown in the above table. All of these pH fall between the limit of 5.3—5.6 without exception.

Besides, the author observed the heat emisssion of the mass of "Tengu-no-mugimeshi" with an earth-thermometer, but he could not withness any evidence of it.

As the tradition tolds us that an ascetic who shut himself up in the mountain, lived on "Tengu-no-mugimeshi," the author tasted a pure part of it, and experienced agar-like taste. The author gave hens these grains which they pecked with delight. This makes us suppose that the exposed "Tengu-no-mugimeshi" in the mountain might be a food for wild birds such as pheasants or quails.

Recently, the author read the report of the Imperial Government In titute for Nutrition[1] which used rats as test animals. According to the report, "Tengu-no-mugimeshi" is entirely worthless as a nutrition, though innocuous. But the fresh sample is said to be eatable like agar, promotes the wringglidg of the intestines and facilitates excretion.

In the table (cf. P. 48), the author stated about a smell of the mass. This smell is attributable to the decomposed product which accompanies the generation of methane gas in the growing soil. The author observed that the gas generated so much as to catch fire, when we brought near an enkindled match.

Besides, the rock—Andesite—in the growing place is more disintegrated than in the ordinary place. Dr. T. KAWAMURA thought that this phenomenon came from the physiological functions of "Tengu-no-mugimeshi. The author also supposed some relationship, and this fact offers a subject for consideration along with the fact that "Tengu-no-mugimeshi" is not discovered except in volcanic regions.

About all these physiological sides of "Tengu-no-mugimeshi," the author will set forth in detail in the physiological section under. (to be continued)

(1) Report of the Imperial Government Institute for Nutrition. Vol. VII. (1934) No. 1, P. 122-129. (Japanese)